TIME DOMAIN ELECTROMAGNETIC SURVEYS FOR ASSISTING IN DETERMINING THE GROUNDWATER RESOURCES ON PROPERTY LOCATED IN THE SOUTH KOHALA DISTRICT ABOVE KAWAIHAE, HAWAII

Project Number 00201

August 2011

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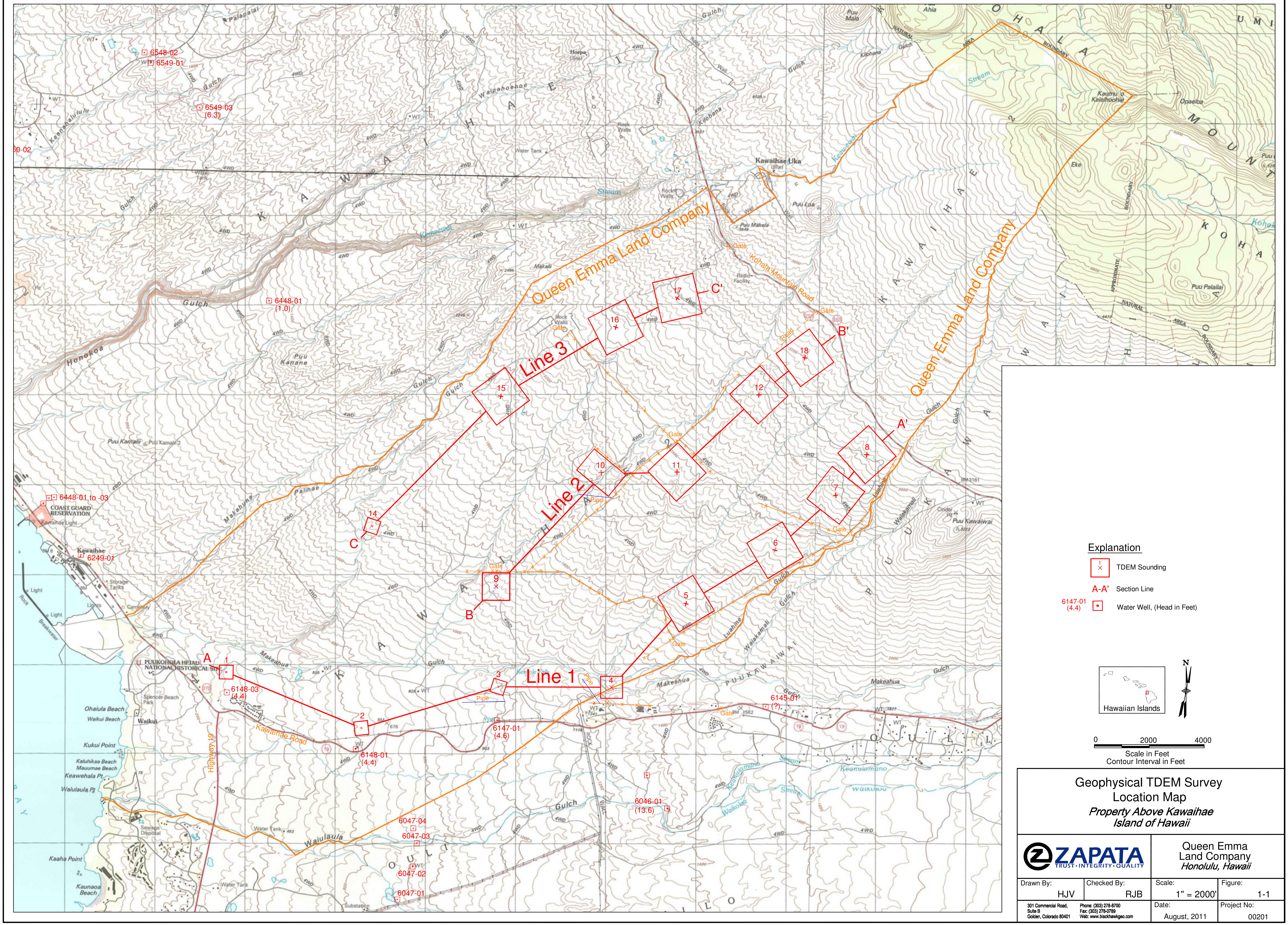
1.0 INTRODUCTION

This report contains the procedures and results of surface Time Domain Electromagnetic (TDEM) geophysical surveys performed for groundwater resource evaluation on property located in the South Kohala District above the town of Kawaihae, Hawaii. The project site included land located both north and east of the junction of Highway 19 and Kawaihae Road toward the town of Kamuela and along the Kohala Mountain Road toward Hawi. Zapata Incorporated (ZAPATA) performed the surveys for Queen Emma Land Company (QELC) and Tom Nance Water Resource Engineering (TNWRE) from July 20 through July 29, 2011.

The main objective of the TDEM surveys was to explore for basal or high-level groundwater on the property. The surveys were conducted at seventeen TDEM sounding sites to help determine the location for future groundwater wells. The project boundary and locations of the TDEM soundings taken during this survey are shown on Figure 1-1.

TDEM is a geophysical method that determines from the surface the geoelectric section (resistivity layering) of the subsurface. From the geoelectric section, information about geology and water quality can be inferred. This is possible because the electrical resistivity of the earth depends on lithology, porosity, degree of saturation, and concentration of dissolved solids in the groundwater. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for water well placement and well completion depths.



Geophysical TDEM Survey
Location Map
Property Above Kawaihae
Island of Hawaii

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Drawn By:	Checked By:	Scale:	Figure:
HJV	RJB	1" = 2000'	1-1

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2.0 GEOLOGY/HYDROGEOLOGY

Groundwater resources occur on the Hawaiian Islands basically in two modes:

- In a basal mode where a lens of fresh water floats on seawater, and
- In a high-level mode where the fresh groundwater occurrence is controlled by damming structures (i.e. dikes, intrusives, etc).

Figure 2-1 illustrates the basic geologic and hydrologic framework of the Island of Hawaii and the two modes of groundwater occurrences. Fresh groundwater may also occur in areas between these two modes, but production is expected to be highly variable. TDEM soundings previously taken on Hawaii have reliably mapped basal mode groundwater and the boundary between fresh water in the basal mode and high-level water occurrences.

Basal mode groundwater is shown to rest approximately at sea level near the ocean surrounding the Island of Hawaii (reference Figure 2-1). This is due to the fact that the volcanic rocks, which comprise the island, allow rainfall to percolate with little impedance directly downward through the rock mass and the fresh water floats directly on seawater encroaching from the ocean. Fresh water flows laterally toward the ocean causing the fresh water lens to be thinner near the shoreline. When groundwater is under static equilibrium conditions, the Ghyben-Herzberg Principle states that for every one foot of fresh water above sea level approximately 40 feet of fresh water will exist below sea level as shown in Figure 2-2. The change from fresh water to seawater (transition zone) at depth may be relatively sharp (i.e. occurring over several tens of feet) or more gradual, depending upon hydrologic flux, horizontal and vertical permeability contrast, and other geologic factors. It is assumed, when resolving TDEM sounding data, that seawater saturated volcanics occur at the midpoint of the transition zone.

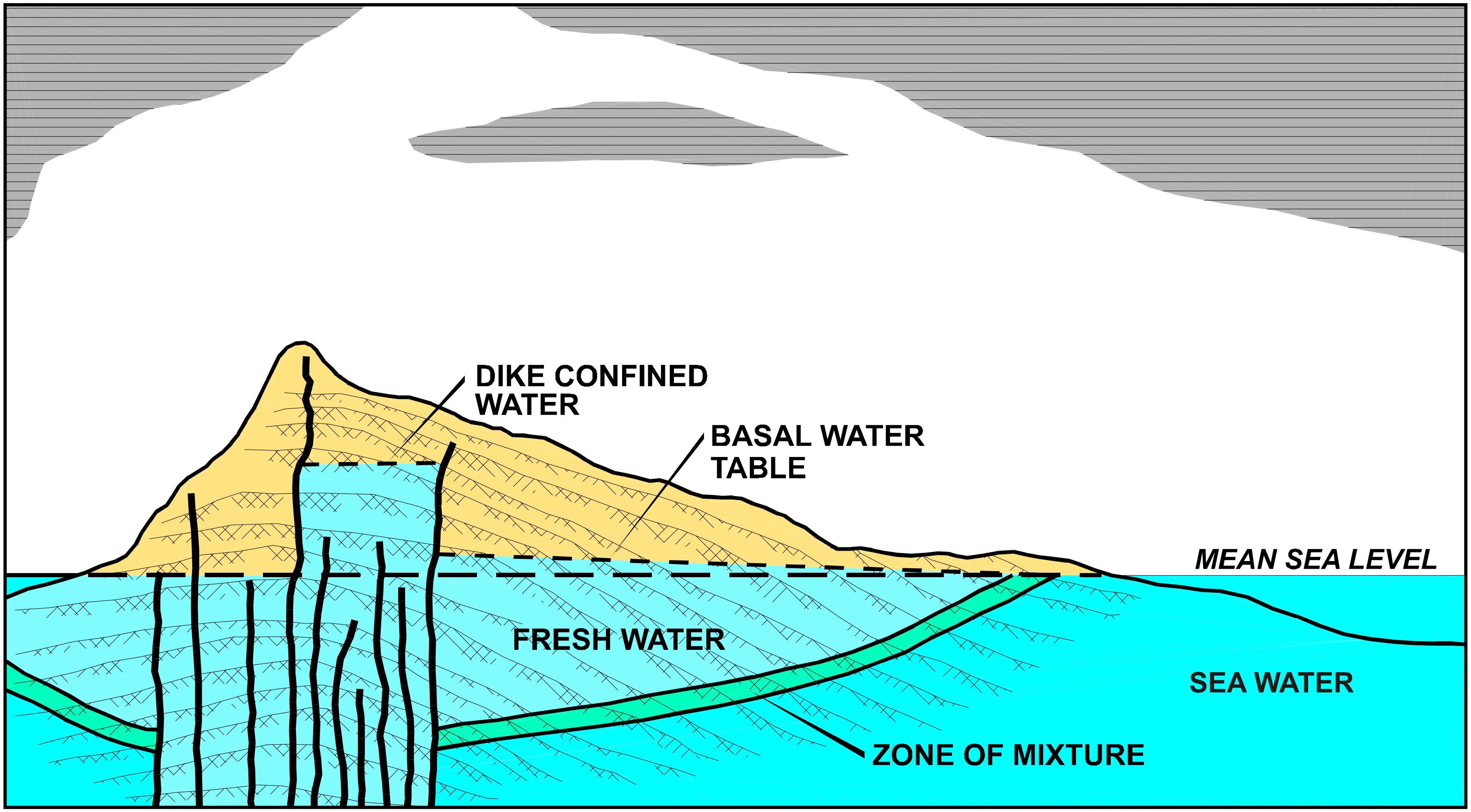
TDEM surveys are utilized to map the resistivity stratification of the subsurface. From numerous TDEM surveys on Hawaii and calibration of TDEM data at groundwater wells, characteristic ranges of subsurface resistivities have been derived for the geologic/hydrologic units shown in Figure 2-3. Some overlap in resistivity values occurs between the units; however, other factors, such as ground elevation, can be used to help separate the units. Therefore, the main geologic/hydrologic units that can be derived from TDEM surveys include:

- Depth to seawater-saturated volcanic rocks. This occurs in basal mode situations, and by using the Ghyben-Herzberg principle the thickness of the basal fresh water lens can be calculated.
- Weathered volcanic layers (laterite). These low to intermediate resistivity units are generally relatively thin layers (100 to 200 feet thick) that normally occur at or near the ground surface.
- Clay-poor and fresh water saturated volcanic rocks. These formations generally exhibit high resistivity values (>500 ohm-m). The extent of fresh water saturation is normally

based on geographic and elevation information, and it should be noted that fresh water layers cannot be directly detected in the TDEM data.

Groundwater damming structures (i.e. intrusives, dikes) are inferred with TDEM data by uncharacteristic sounding curves (distorted by 2-D structures), and by soundings that change between detection of seawater at depth (indicating basal mode groundwater) and soundings that map high resistivities to depths below sea level (indicating high-level groundwater).

Figure 2-4 illustrates the combined geologic and topographic map showing lava flows from the Mauna Kea Volcano (Qhm) and cinder cones, fissure vents from the Kohala Volcano (Qpl, Qhw and Qhwb) in the project area. The locations of the TDEM soundings taken during this survey are also shown on the map.



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Honolulu, Hawaii

Schematic Hydrogeologic Cross Section Island of Hawaii

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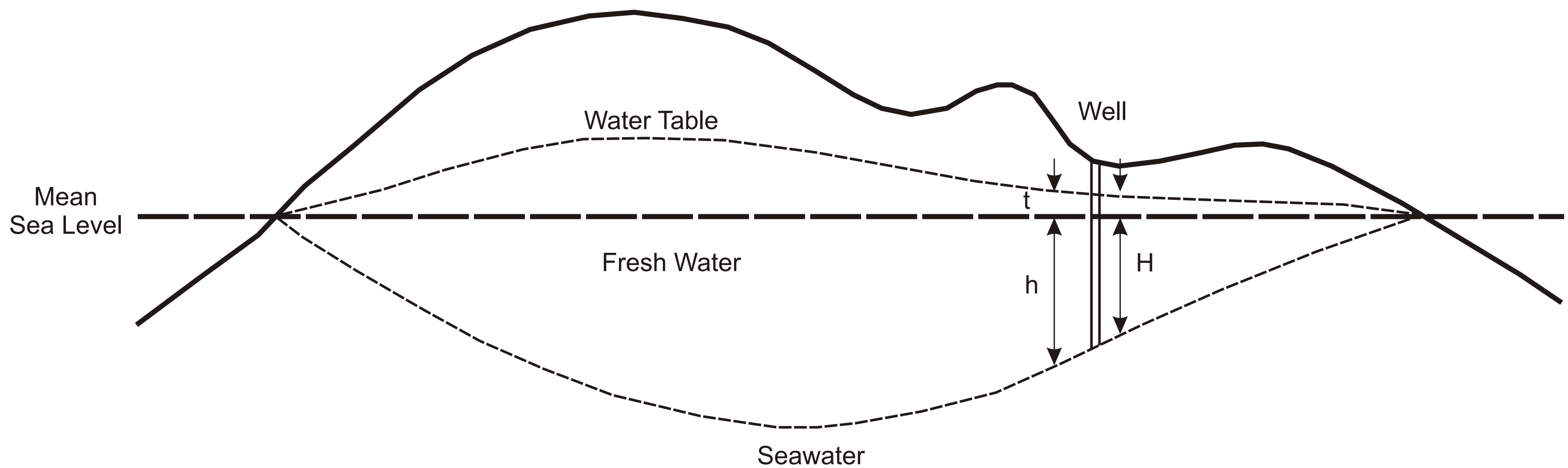
00201	August, 2011	HJV	RJB	No Scale	2-1



$$t = 1/40\ (h)$$

From: Herzberg

ZAPATA TRUST·INTEGRITY·QUALITY	**Queen Emma Land Company** *Honolulu, Hawaii*	**Illustration of the Ghyben-Herzberg Principle**

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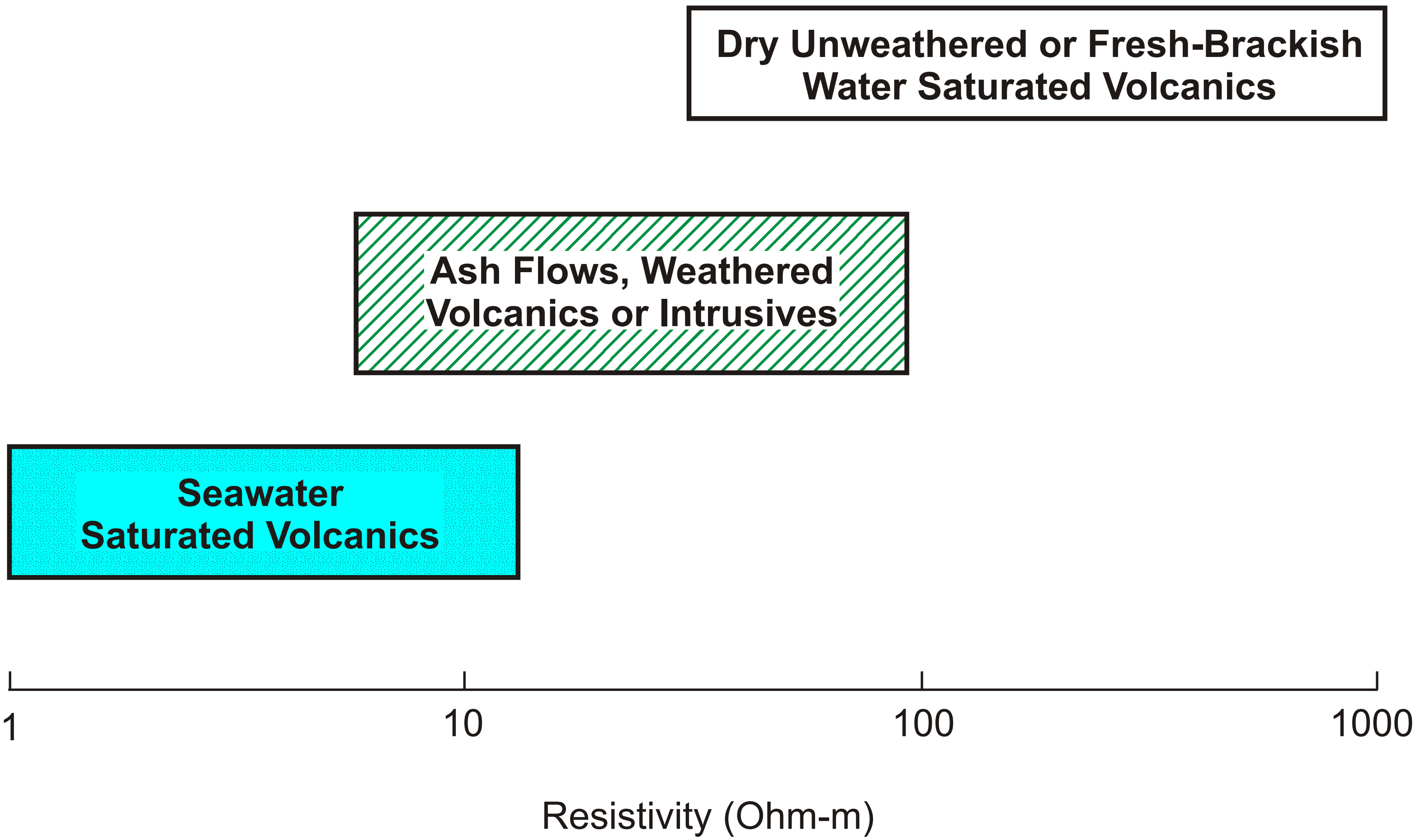

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Characteristic Resistivity Ranges
Property Above Kawaihae
Island of Hawaii

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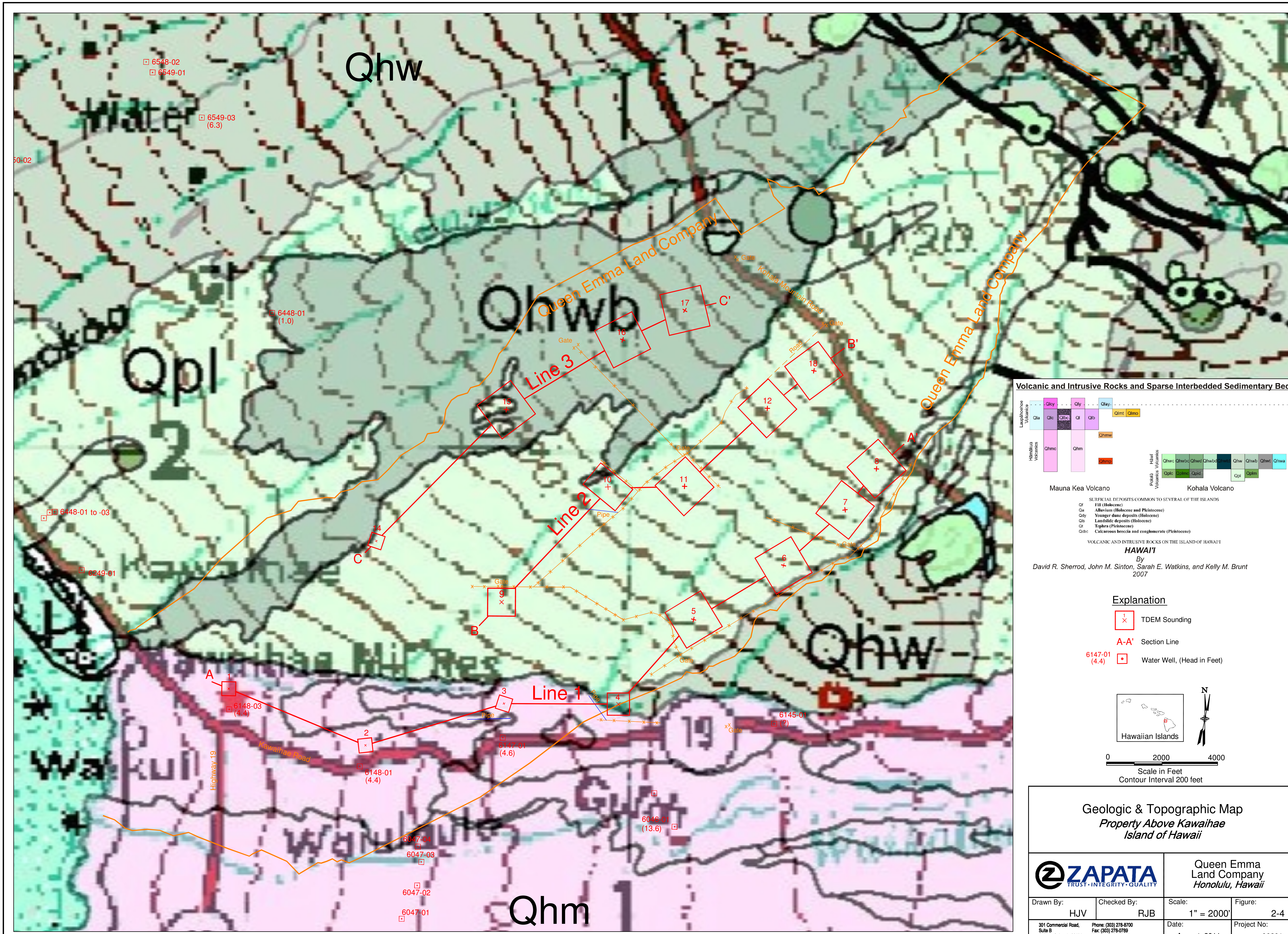

Geologic & Topographic Map
Property Above Kawaihae
Island of Hawaii

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3.0 DATA ACQUISITION AND LOGISTICS

ZAPATA mobilized a field crew consisting of a project geophysicist and geophysical technician to perform the geophysical surveys. The field crew and TDEM equipment were mobilized from Golden, Colorado to Kailua-Kona, Hawaii. Prior to conducting the surveys, ZAPATA personnel coordinated with QELC and TNWRE personnel to determine property access with Parker Ranch personnel. During the field work the project geophysicist coordinated with TNWRE on a daily basis to relay preliminary data results and determine project direction. A daily log of field activities during the TDEM surveys is given in Table 3-1.

The Geonics EM37 geophysical system was used for the TDEM surveys. The EM37 system includes both a portable motor-generator powered transmitter and a PROTEM digital receiver. The main purpose of the TDEM measurements is to derive both the vertical and lateral variations in the geoelectric section (resistivity) of the subsurface. To accomplish this, TDEM soundings were collected using a central-loop array at each location. Transmitter wire-loops with square dimensions were constructed using 12-gauge insulated copper wire laid on the ground surface (illustrated in Figure 3-1). Depending upon ground elevation, the dimensions of the transmitter wire-loops used during the survey varied from 500 by 500 feet to 1,000 by 1,000 feet and up to 1,500 by 1,500 feet for the TDEM soundings. The EM37 transmitter was placed in each transmitter loop and square-wave current pulses were driven through the wire-loop using a current ranging from 13 to 23 amperes. The current pulses induce eddy current flow in the subsurface of the ground. A solid-core receiver coil (1-meter diameter) attached to the PROTEM receiver was positioned in the center of each wire-loop and was used to record the decay of the secondary magnetic field from the eddy currents induced in the subsurface. The effective exploration depth of a 1,000 by 1,000-foot transmitter wire-loop array has been determined to be approximately 2,500 feet below the ground surface. Therefore, at surface elevation of 1,000 feet, a search depth of approximately 1,500 feet below sea level is obtained. Greater exploration depths are reached with larger transmitter wire-loops and there are several factors that affect the depth of investigation; these include ground resistivity (in ohm-m) and surrounding ambient cultural interference (i.e. 60-cycle powerline, metal pipelines, etc). The principles of TDEM with case histories are given in a technical note in Appendix A.

The TDEM data collected at each sounding site consisted of measurements utilizing several receiver gain settings and two transmitter frequencies in order to obtain data over the longest time interval possible. The data were recorded using base frequencies of 3 and 30 Hz to obtain the maximum search depth for each TDEM sounding. For data quality control (QC) purposes, additional measurements were collected at a minimum of two locations, offset 200 feet in different directions from the center, for comparison to the central-loop data. The data from each sounding were recorded in solid-state memory in the PROTEM receiver and transferred daily to a personal computer (PC) for processing. The TDEM data collected at sixteen of the seventeen sites were of excellent quality. However, Sounding 6 was determined to be distorted due to local cultural interference (i.e. metal pipeline, fenceline, etc.) that affected the measurement of the

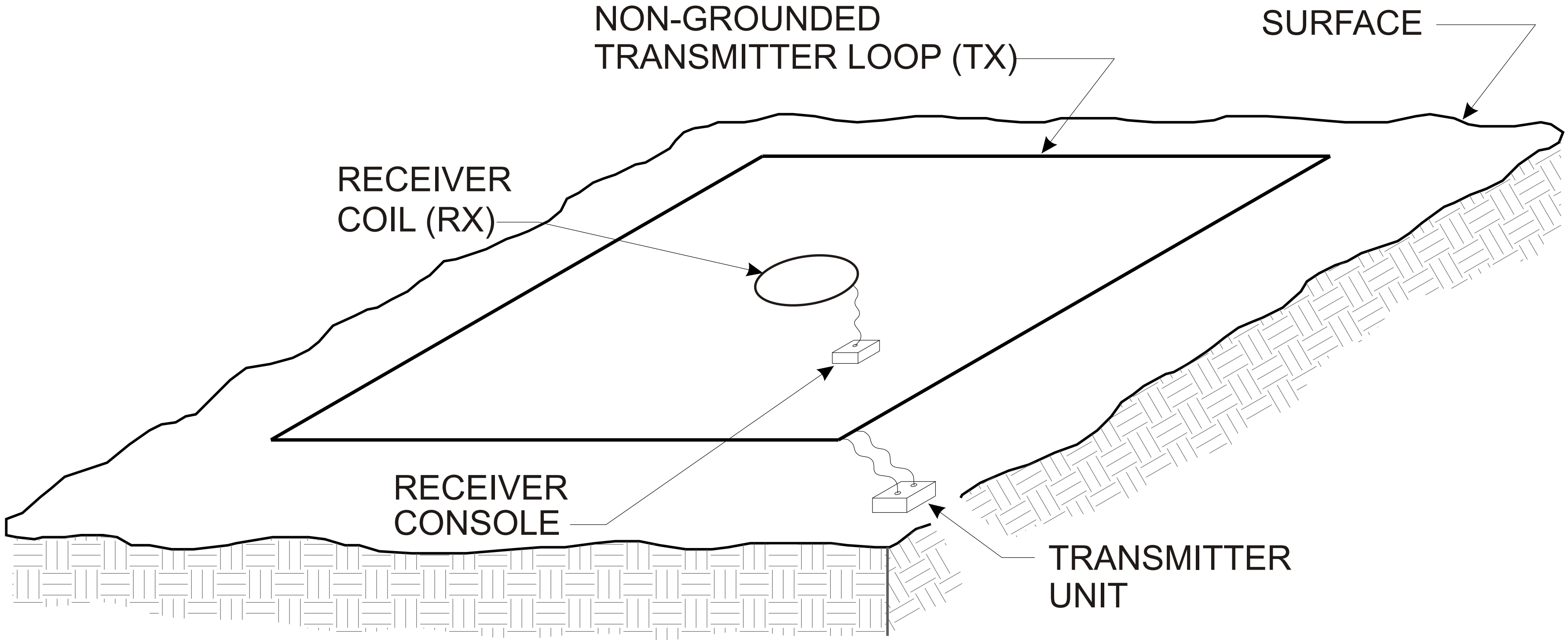
TDEM data. The QC offset data sets for this sounding were also determined to be affected by the local cultural interference at this site.

The corners of the transmitter wire-loops were registered to road junctions, gulches and fences located on the topographic map of the project site. In several cases, landmarks such as property gates were used to position the wire-loops on the map along with using a measuring device (hip-chain) and compass to locate the loop corners. In addition, a hand-held global positioning system (GPS) with differential position accuracy of 20 feet was used to measure the center and transmitter corner of each sounding. The GPS coordinates were then used to position each loop center on a geo-referenced topographic map and the loop center elevation was subsequently derived from that position. A total of seventeen TDEM soundings were measured during 10 days of fieldwork. The GPS coordinates and elevations of the TDEM transmitter loop centers and corners are given in Table 3-2 in Appendix B.

Table 3-1
Daily Log of Field Activities for TDEM Survey
Queen Emma Land Company, South Kohala District, Kawaihae, Hawaii

Date (2011)	Activity
July 18	Pack up and ship TDEM equipment from another project on Oahu, HI to Kailua-Kona, HI.
July 19	Mobilize ZAPATA personnel from Honolulu, HI to Kailua-Kona, HI. Meet with Parker Ranch personnel in Kamuela and receive keys for gates to property. Unpack TDEM equipment at hotel and organize into SUV.
July 20	Start TDEM survey. Recon Line 1. Lay out wire-loop and collect data on Sounding 1. Lay out wire-loop and acquire data on Sounding 2. Lay out wire-loop and take data on Sounding 3. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 21	Line 1; lay out wire-loop and collect data on Sounding 4. Lay out wire-loop and take data on Sounding 5. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 22	Line 1; lay out wire-loop and acquire data on Sounding 6. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 23	Line 1; lay out wire-loop and collect data on Sounding 7. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 24	Move to Line 2. Lay out wire-loop and take data on Sounding 10. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 25	Line 2; lay out wire-loop and collect data on Sounding 11. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 26	Line 2; lay out wire-loop and acquire data on Sounding 12. Move to Line 3; lay out wire-loop and take data on Sounding 15. Download data and perform preliminary analysis. Discuss results with TNWRE.

July 27	Line 3; lay out wire-loop and collect data on Sounding 16. Lay out wire-loop and take data on Sounding 17. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 28	Move to Line 2; lay out wire-loop and acquire data on Sounding 18. Move to Line 1; lay out wire-loop and collect data on Sounding 8. Download data and perform preliminary analysis. Discuss results with TNWRE.
July 29	Move to Line 2; lay out wire-loop and collect data on Sounding 9. Move to Line 3; lay out wire-loop and collect data on Sounding 14. Download data and perform preliminary analysis. Discuss results with TNWRE. Finish survey.
July 30, 31	Days off.
August 1, 2	Demobilize ZAPATA personnel from Kailua-Kona, HI to Golden, CO.



ZAPATA TRUST · INTEGRITY · QUALITY	**Queen Emma Land Company** *Honolulu, Hawaii*	**Schematic layout of TDEM system with locations of TX and RX for Central Loop Array measurements**

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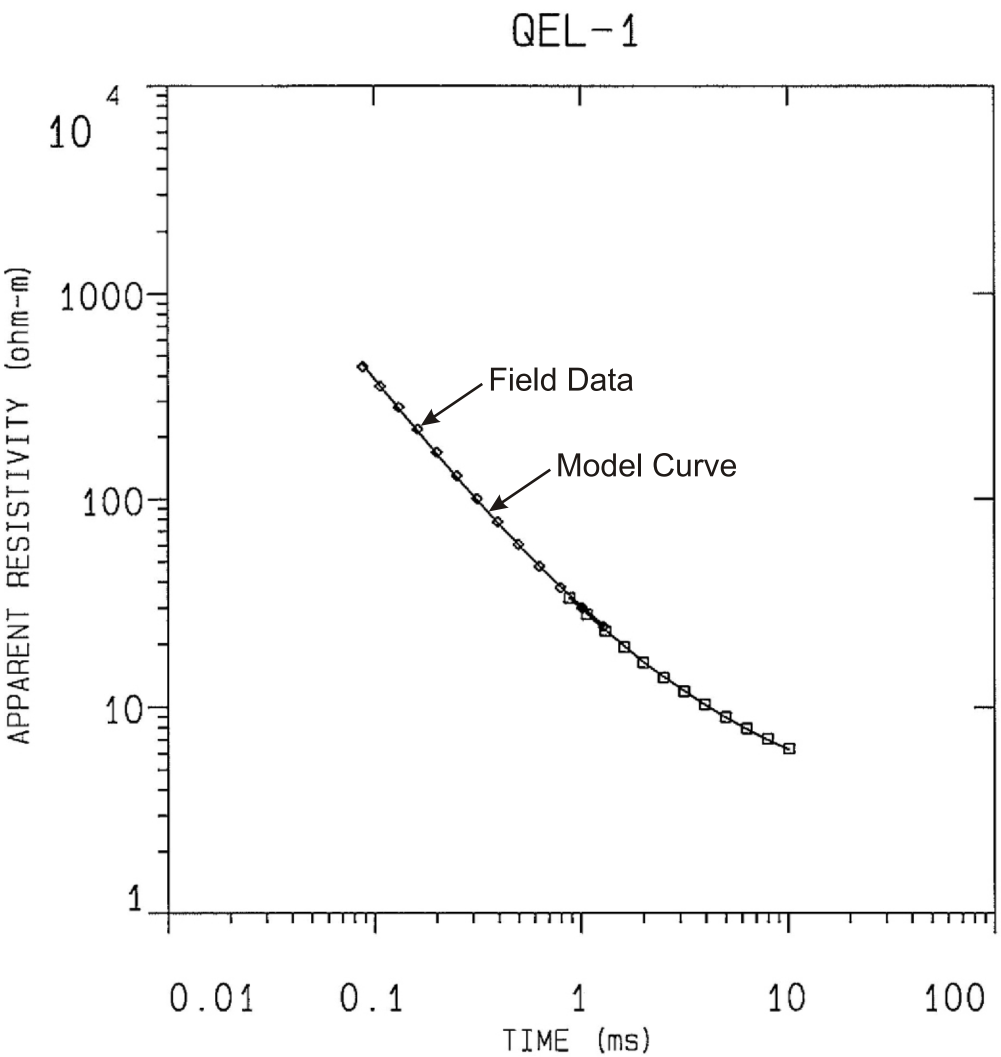
4.0 DATA PROCESSING

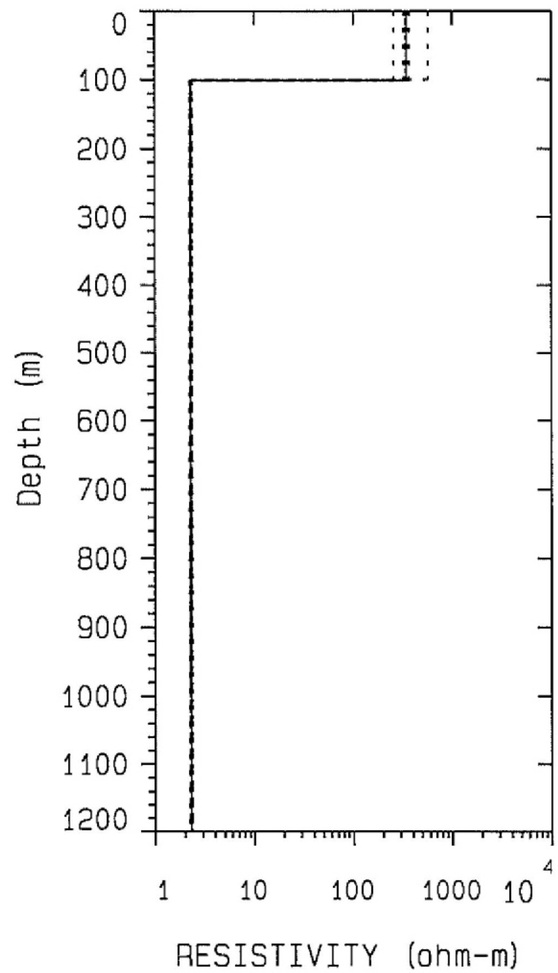
The geophysical field data collected for each TDEM sounding was transferred from the Geonics PROTEM TM digital receiver to a PC for editing and processing. The processing of TDEM data begins with averaging of the electromotive forces recorded for positive and negative receiver polarities. Next, the measurements collected at two base frequencies (3 and 30 Hz) and several amplifier gains are combined to give one voltage decay curve (transient). The electromotive forces (EMFs) collected from 20 logarithmical spaced time-channels (gates) of the decay curve are subsequently entered into the TEMIXXLTM (Interpex Ltd.) inversion program. The data are then used to obtain a one-dimensional (1-D) geoelectric section that best matches the observed (field data) decay curve from each sounding.

The TEMIXXL inversion program requires an initial model of the geoelectric section measured. The initial model includes the number of layers, resistivities and thickness for each of the layers. This model is usually derived from knowledge of the geologic section or from data obtained from drillholes or electric logs. The inversion program is then allowed to adjust the layer thickness and the resistivities, so that the model curve converges to best fit the field data. The inversion program does not change the total number of layers within the model curve, but allows all other parameters to change freely or they can be fixed constant. To determine the influence of the number of layers on the solution, separate inversions with a different number of layers are modeled for the sounding data. Subsequently, the model with the least number of layers that best fits the field data is used.

An example of the output of the inversion program is shown on Figure 4-1 for Sounding 1. The figure shows the measured data points (in terms of apparent resistivity) superimposed on a solid line on the left panel. The solid line represents the computed forward model for the geoelectric section on the right panel. The geoelectric section is the best match obtained by the inversion program. Figure 4-2 shows the tabulated inversion parameters consisting of measured data, computed data for best match solutions and an example of the table of inversion statistics. A two-layer inversion model is shown for Sounding 1. The model displays an upper layer with high resistivity (344 ohm-m) overlying a second layer with very low resistivity (2.3 ohm-m). The depth to the top of the second layer is modeled at -52 feet below sea level (bsl) in the section. The second layer is interpreted as volcanic units saturated with conductive seawater.

The interpreted geoelectric section derived from each TDEM sounding is not unique. The magnitude of each individual layer resistivity and thickness can normally be varied within a limited range with no significant change to the fit of the geoelectric model of the data. This variation is termed equivalence. An equivalence analysis was performed for each TDEM sounding. Both Figures 4-1 and 4-2 also show the equivalence analysis for Sounding 1. This sounding is typical of the TDEM data which shows a +/-5% equivalence in depth determinations and +/-10% in individual layer resistivities. The inversion results for each TDEM sounding are given in Appendix B.





ZAPATA TRUST·INTEGRITY·QUALITY	**Queen Emma Land Company** *Honolulu, Hawaii*			**Sounding QEL-1 Example Inversion Output Apparent Resistivity Curve** *Property Above Kawaihae Island of Hawaii*		
301 Commercial Road, Suite B Golden, Colorado 80401 Phone: (303) 278-8700 Fax: (303) 278-0789 Web: www.blackhawkgeo.com	Project No: 00201	Date: August, 2011	Drawn By: HJV	Checked By: RJB	Scale: No Scale	Figure: 4-1

DATA SET: QEL-1

CLIENT: Queen Emma Land
LOCATION: Parker Ranch
COUNTY: South Kohala
PROJECT: Property Above Kawaihae
LOOP SIZE: 152.000 m by 152.000 m
COIL LOC: 0.000 m (X), 0.000 m (Y)
SOUNDING COORDINATES: E: 1.0000 N: 100.0000

DATE: 07-20-11
SOUNDING: 1
ELEVATION: 85.00 m
EQUIPMENT: Geonics PROTEM
AZIMUTH:
TIME CONSTANT: NONE
SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 1.793 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	(ft)	CONDUCTANCE (Siemens)
			85.00	280.0	
1	344.2	100.9	-15.92	-52.5	0.293
2	2.30				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	257.915	344.236	575.387
	2	2.243	2.303	2.363
THICK	1	99.830	100.921	101.538
DEPTH	1	99.830	100.921	101.538

Equivalence Analysis

CURRENT: 18.00 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 100.00 muSEC

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.881	1477.7	1468.0	0.658
2	1.06	1198.4	1184.6	1.15
3	1.31	943.9	931.1	1.36
4	1.61	732.3	718.7	1.86

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
5	2.00	551.3	543.5	1.40
6	2.50	405.5	400.3	1.28
7	3.14	290.8	288.4	0.838
8	3.95	203.2	203.3	-0.0907
9	4.99	139.5	140.2	-0.498
10	6.31	93.75	94.85	-1.17
11	7.99	61.69	62.87	-1.92
12	10.14	40.12	40.86	-1.83

CURRENT: 18.00 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 3 RAMP TIME: 100.00 muSEC

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
13	0.0881	9753.2	9336.9	4.26
14	0.106	8329.8	8293.1	0.440
15	0.131	7145.8	7273.8	-1.79
16	0.161	6146.7	6319.2	-2.80
17	0.200	5280.5	5424.4	-2.72
18	0.250	4475.5	4588.0	-2.51
19	0.314	3749.1	3821.3	-1.92
20	0.395	3099.1	3139.5	-1.30
21	0.499	2523.9	2535.1	-0.442
22	0.631	2022.7	2014.9	0.387
23	0.799	1589.4	1572.2	1.08
24	1.01	1224.8	1202.6	1.81
25	1.28	922.3	901.5	2.25

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.07		
P 2	-0.05	0.96	
T 1	0.02	0.00	1.00

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Sounding QEL-1
Example of Tabulated Data From Inversion
Property Above Kawaihae
Island of Hawaii

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00201	August, 2011	HJV	RJB	No Scale	4-2

5.0 INTERPRETATION AND RESULTS

5.1 TDEM SOUNDING DATA

From each TDEM sounding, the geoelectric section of the subsurface is derived. The results of the one-dimensional (1-D) inversion from the individual TDEM soundings can be linked together as layers with similar resistivities, to create a 2-D geoelectric cross-section along a transect line. A total of seventeen TDEM soundings were collected on the QELC property during the project (reference Figure 1-1), from which three geoelectric cross-sections were generated. The correlation between the geoelectric layers and lithologic units (illustrated on Figure 2-3) was used to interpret the geoelectric cross-section.

5.2 GEOELECTRIC CROSS-SECTION – LINE 1 (A-A')

Figure 5-1 shows the layered geoelectric cross-section interpreted from TDEM data collected along Line 1. The soundings are located along the Makeahua and Luahine Gulches in a roughly southwest to northeast profile. Soundings 1, 2, and 3 were located near water wells along the north side of Kawaihae Road. Due to several cultural features (pipeline and fence), Sounding 4 was positioned near the southern property boundary. Soundings 5, 6, 7 and 8 were located north of a 4WD road and fence line which ran along the length of the property in this area of the ranch.

In the geoelectric cross-section two-, three- and four-layer models are interpreted for the soundings. A two-layer section is interpreted for Soundings 1, 2 and 3, while a three-layer section is interpreted for Sounding 4. The upper layer (beneath Soundings 1, 2 and 3) exhibits high resistivity that ranges from 344 to >1,000 ohm-m, which is interpreted as dry, clay-poor volcanic formations located both above and below sea level in the section. Where the layer occurs below sea level it is expected to be saturated with fresh-brackish basal mode groundwater. The lower layer in the cross-section shows low resistivity (1.3 to 5.1 ohm-m) and is interpreted to represent seawater saturated volcanic layers beneath the four soundings on the western end of the survey line. The calculated thickness of the fresh-brackish basal lens beneath Sounding 1 is 52 feet (1.3 feet head), and Sounding 2 is 36 feet (0.9 feet head). The thickness of the basal lens is calculated at 72 feet (1.8 feet head) beneath Soundings 3 and 4. Water well information indicates that State Wells 6147-01 (4.6 feet), 6148-01 (4.4 feet) and 6148-03 (4.4 feet) are reported to contain basal (brackish) groundwater with static water levels (head) as shown for these wells (per com T. Nance). The TDEM sounding data shows fair comparison to the water wells in these areas of the site. The difference in head shown at these locations may be due to poorly permeable lava flows which are interbedded with more permeable flows or other geologic features at depth in these regions.

A three-layer section is interpreted for both Soundings 5 and 7. Sounding 6 was determined to be affected by local cultural interference (e.g. metal pipeline, fence) and therefore was not used in the interpretation. The upper layer in the cross-section shows intermediate resistivity (101 to 112 ohm-m) and is interpreted as a thin weathered surface layer. The second layer exhibits high resistivity (427 to 849 ohm-m) and is interpreted as dry, clay-poor volcanic formations located both above and below sea level at depth beneath these two soundings. Where the second layer occurs below sea level, it is expected to be saturated with fresh-brackish basal mode groundwater. The third layer in the section beneath Sounding 5 shows intermediate resistivity (84 ohm-m), occurring at a depth of 1,155 feet bsl, while beneath Sounding 7 a 61-ohm-m layer occurs at a depth of 554 feet bsl. These lower layer resistivities are interpreted to possibly be caused by: 1) Data being distorted by 2-D geologic structures (e.g. dikes), and/or 2) The presence of significant amounts of fine-grained materials (clays) at depth in lava flows in this area.

State Well 6145-01 is located approximately 4,600 ft southeast of Sounding 5 (near Kawaihae Road) and is reported to contain brackish groundwater, and the static water level was unknown at the time of this survey. It is possible that subsurface geologic features are causing non-layered earth conditions (e.g. 2-D dike, intrusive) that act as possible groundwater damming structures beneath this area of the site. However, there are no surface geologic features (i.e. cones, vents, etc.) shown in the immediate vicinity of these soundings to confirm these subsurface conditions.

The TDEM results for Sounding 8 show high resistivity (>1,000 ohm-m) layers that occur both above and below sea level to a maximum exploration depth of approximately 1,200 feet bsl. Where the third layer occurs below sea level it is expected to be saturated with fresh-brackish basal mode groundwater at depth beneath this sounding. With the present sounding data, the location of a groundwater barrier is interpreted to be located downhill from Sounding 8. Therefore, Sounding 8 is interpreted to be located above a possible groundwater damming structure, which may consist of a fairly abrupt subsurface feature such as a dike or possibly from low permeability units within the lava flows. In this area of the property the potential for high-level groundwater may exist beneath Sounding 8.

5.3 GEOELECTRIC CROSS-SECTION – LINE 2 (B-B')

The layered geoelectric cross-section from data taken along Line 2 is shown in Figure 5-2. The soundings are located in the central portion of the property in a southwest to northeast profile. Sounding 9 was located on the western end of the line while Soundings 10, 11, 12 and 18 were positioned along the transect to avoid numerous cultural features (pipelines and fences) located in this portion of the ranch.

In the geoelectric cross-section a two-layer model is interpreted for Sounding 9. The top layer displays a high resistivity of 696 ohm-m, which is interpreted as dry, clay-poor volcanic formations located both above and below sea level in the section. The second layer beneath Sounding 9 exhibits low resistivity (6.9 ohm-m) and is interpreted to represent seawater-saturated volcanic layers at depth below this sounding. The calculated thickness of the fresh-brackish basal groundwater lens is 212 feet (5.3 ft head) beneath this sounding.

A four-layer cross-section is interpreted for Soundings 10, 11, 12 and 18 along this line. The upper layer in the geoelectric section exhibits resistivities that range from 64 to 122 ohm-m and is interpreted as weathered surface soils across the site. The thickness of the top layer is estimated to vary from 100 to 120 feet along the line. The second layer in the section shows high resistivity (>1,000 ohm-m) that is interpreted to represent dry clay-poor volcanic layers occurring above sea level. The third and fourth layers in the section beneath Sounding 10 show intermediate resistivities (13 to 80 ohm-m) which are interpreted to be weathered or altered volcanic layers at depth beneath this sounding. The third layer beneath Soundings 11 and 12 shows high resistivity (113 to 147 ohm-m) and is interpreted as dry, clay-poor volcanic layers located above sea level. Where the third layer occurs below sea level, it is expected to be saturated with fresh-brackish basal groundwater. The fourth layer in the section beneath Soundings 11 and 12 shows low resistivity (10 ohm-m) to occur at an approximate depth of exploration of 925 feet bsl and 600 feet bsl, respectively. The fourth layer resistivities at depth are interpreted to possibly be the result of: 1) Distortion of the data by 2-D geologic structures (e.g. dikes), or 2) The presence of fine-grained materials (clays) in lava flows in these areas.

Sounding 18 shows high resistivity (>1,000 ohm-m) layers that occur both above and below sea level to the maximum exploration depth. Where the fourth layer occurs below sea level in the section, it is expected to be saturated with fresh-brackish basal mode groundwater at depth beneath this sounding. A groundwater barrier is interpreted to be located between Soundings 12 and 18 and thus, Sounding 18 is interpreted to be located above a groundwater damming structure (e.g. dike, intrusive) in this area of the site. The potential for high-level groundwater may exist beneath this area of the property.

5.4 Geoelectric Cross-Section – Line 3 (C-C')

Figure 5-3 shows the layered geoelectric cross-section interpreted from TDEM data collected along Line 3. The soundings are located near the northern property boundary along Palihae Gulch in a southwest to northeast profile. Sounding 14 was located on the western end of the traverse while Soundings 15, 16, and 17 were placed along the line with increasing elevation toward the Kohala Mountain Road.

The geoelectric cross-section for Line 3 is very similar to Line 2. In the cross-section a three-layer model is interpreted for Sounding 14. The upper layer shows an intermediate resistivity (60 ohm-m) that is interpreted as weathered surface layer with a thickness of 100 feet. The second layer displays a high resistivity (>1,000 ohm-m), and is interpreted as dry, clay-poor volcanic layers located both above and below sea level in the section. The third layer beneath Sounding 14 exhibits low resistivity (14 ohm-m). Although the resistivity value is higher than what is normally expected for seawater (3.0 ohm-m), in this case, it is interpreted to represent seawater-saturated volcanic layers at depth below this sounding. The calculated thickness of the fresh-brackish basal groundwater lens is 147 feet (3.7 feet head) beneath the sounding.

A four-layer cross-section is interpreted for Soundings 15, 16 and 17 along this line. The upper layer in the geoelectric section exhibits resistivities that range from 78 to 287 ohm-m and is interpreted as weathered surface soils along the profile. The thickness of the upper layer is estimated to vary from 100 to 180 feet along the line. The second layer in the section shows high resistivity (>1,000 ohm-m) that is interpreted to represent dry clay-poor volcanic layers occurring above sea level. The third and fourth layers in the section beneath Sounding 15 show intermediate resistivities (14 to 85 ohm-m) which are interpreted to be weathered or altered volcanic layers at depth beneath this sounding. The third layer beneath Soundings 16 and 17 shows high resistivity (200 to 268 ohm-m) which is interpreted as dry, clay-poor volcanic layers located above sea level. Where the third layer occurs below sea level it is expected to be saturated with fresh-brackish basal groundwater. The fourth layer in the section beneath these two soundings exhibits low to intermediate resistivity (6.0 to 27 ohm-m) which occurs at a depth of approximately 990 feet bsl and 950 feet bsl, respectively. These fourth-layer resistivities are interpreted to possibly be the result of: 1) Distortion of the data by 2-D geologic structures (e.g. dikes), or 2) The presence of fine-grained materials (clays) in lava flows in this area of the site.

5.5 HYDROGEOLOGIC INTERPRETATIONS

Table 5-1 contains the approximate thickness of the fresh-brackish water lens calculated from the elevation of the seawater interface interpreted from the TDEM soundings taken on the QELC property. The table includes the value of static water level (head) calculated by using the Gheyben-Herzberg Principle.

Table 5-1
Hydrogeologic Information Derived From TDEM Soundings
QUEEN EMMA LAND COMPANY, KAWAIHAE, HAWAII
(Values in Feet)

Sounding Number	Surface Elevation	Elevation of Top of the Conductive Layer	Calculated Static Water Level (Head) Using Ghyben-Herzberg Principle	Approximate Thickness of Fresh-Brackish Water Lens
1	280	-52	1.3	53
2	600	-36	0.9	37
3	980	-72	1.8	74
4	1,220	-72	1.8	74
5	1,760	*	*	*
6	2,280	**	**	**
7	2,720	*	*	*
8	3,000	*	*	*
9	1,270	-212	5.3	217
10	2,000	*	*	*
11	2,360	*	*	*

12	2,900	*	*	*
13	Unused	Unused	Unused	Unused
14	1,160	-147	3.7	151
15	1,920	*	*	*
16	2,615	*	*	*
17	2,960	*	*	*
18	3,240	*	*	*

*Sounding where seawater was not detected.
**Sounding determined to be distorted by local cultural interference (e.g. buried pipeline, etc.).

The TDEM data is further summarized on the interpretation map shown in Figure 5-4. On this figure the soundings are color coded as follows:

- Blue – colored soundings detected seawater at depth. The depth to the seawater interface is given (e.g. -212 feet).
- Green – colored soundings are interpreted to be located within areas that have detected intermediate resistivity in which 2-D structures (e.g. dikes, ash flows, etc) have likely distorted the true resistivity values.
- Yellow – colored soundings are located in areas that have potential for high-level groundwater.

On the map Soundings 1, 2, 3, 4, 9 and 14 exhibit a low resistivity layer (1.3 to 14 ohm-m) that is detected below sea level. A fresh-brackish water lens is interpreted to occur in the basal mode beneath these soundings and it is expected to be thickest beneath Sounding 9, at 212 feet (5.3 feet head). The accuracy of determining the depth to the seawater interface from TDEM soundings is estimated to be +/-5% of the total depth calculated in the sounding, (e.g. from the ground surface to the seawater interface).


Line 1
A
SW
A'
NE
Sounding Number
1
(EL. 280')
Well 6148-03
(Located 1,200' South)
(Head 4.4')
2
(EL. 600')
Well 6148-01
(Located 800' South)
(Head 4.4')
3
(EL. 980')
Well 6147-01
(Located 1,100' South)
(Head 4.6')
4
(EL. 1220')
5
(EL. 1760')
Well 6145-01
(Located 4,600' SE of Line)
(Head ?)
6
(EL. 2280')
7
(EL. 2720')
8
(EL. 3080')
Ground Surface
Sea Level
TD?
344
540
>1000
460
92
101
427
517
849
112
309
>1000
2.3
1.3
1.5
5.1
84
61
Discontinuity Position and Width Uncertain
Potential High-Level Ground Water
Approximate Exploration Depth
Elevation (Feet)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
Explanation
517 Resistivity (ohm-m)
Resistivity Boundary (Dashed Where Uncertain)
Inferred Lateral Discontinuity
Distorted Sounding (Due to Cultural Interference)
Laterite Soil (Clay Rich Layer)
Dry Clay Poor or Fresh-Brackish Water Saturated Volcanics
Inferred 2-D Structure (Possible Ash Falls, Weathered Volcanics or Intrusives)
Seawater Saturated Volcanics
500 Ft.
0
0
1000 Ft.
Scale in Feet
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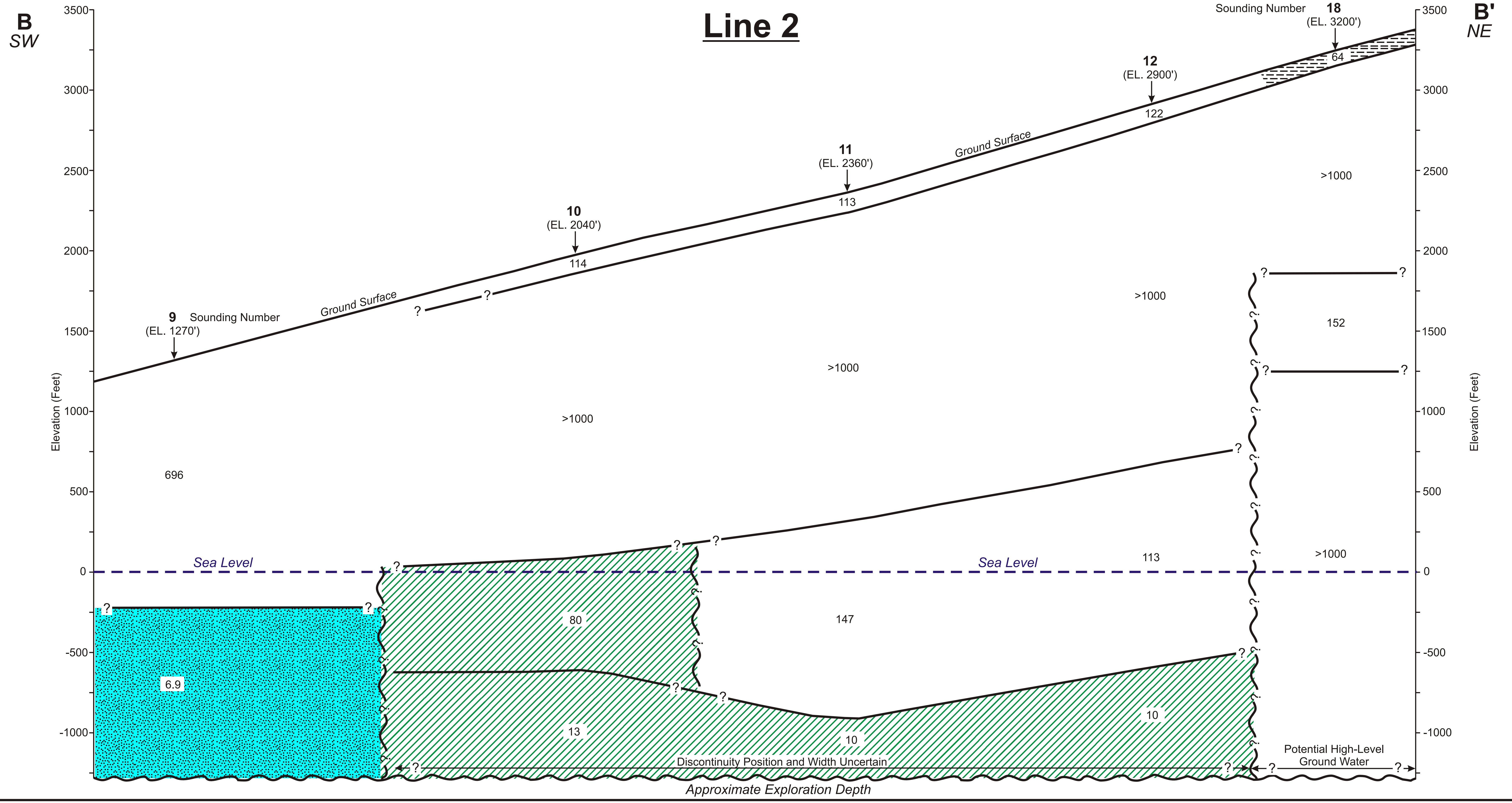
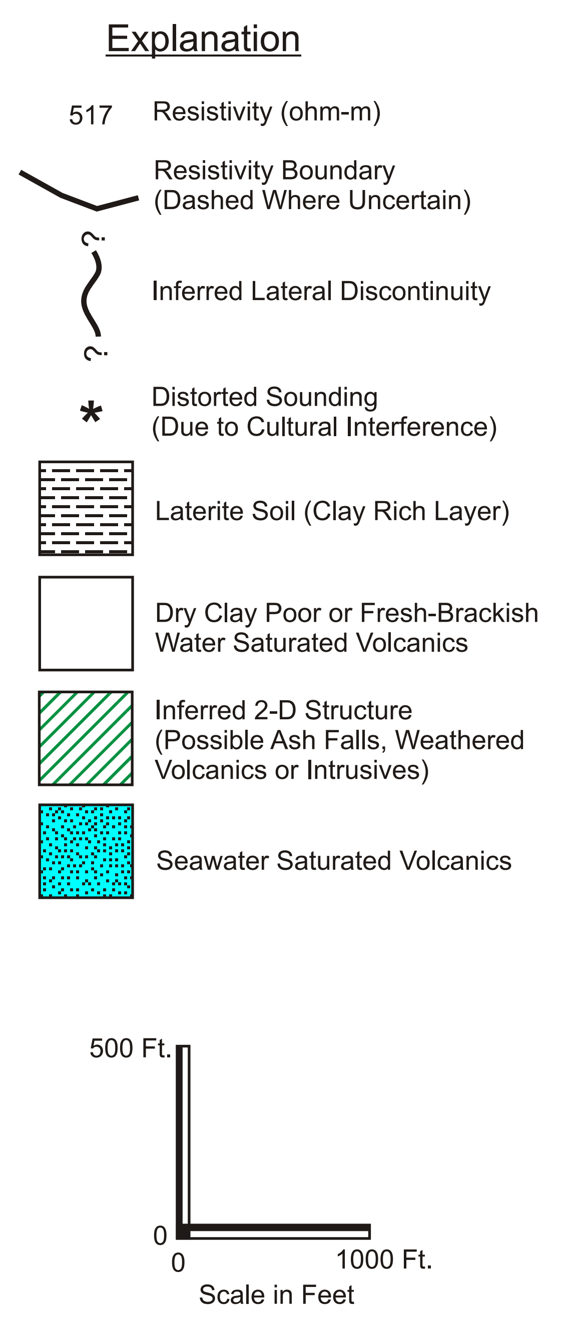
Phone: (303) 278-8700 Fax: (303) 278-0789 Web: www.blackhawkgeo.com
Queen Emma Land Comany
Honolulu, Hawaii
Geoelectric Cross-Section from 1-D TDEM Inversions Line 1 A-A'
Property Above Kawaihae Island of Hawaii
Project No: 00201
Date: August, 2011
Drawn By: HJV
Checked By: RJB
Scale: As Shown
Figure: 5-1





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Queen Emma Land Company
Honolulu, Hawaii

Geoelectric Cross-Section from 1-D TDEM Inversions Line 2 B-B'
Property Above Kawaihae Island of Hawaii

Project No:	Date:	Drawn By:	Checked By:	Scale:	Figure:
00201	August, 2011	HJV	RJB	As Shown	5-2

Line 3
C
SW
C'
NE
Sounding Number
14 Sounding Number
(EL. 1160')
15
(EL. 1920')
16
(EL. 2620')
17
(EL. 2960')
Ground Surface
Sea Level
Elevation (Feet)
>1000
60
134
287
268
200
14
85
6.0
27
Discontinuity Position and Width Uncertain
Approximate Exploration Depth
Explanation
517 Resistivity (ohm-m)
Resistivity Boundary (Dashed Where Uncertain)
Inferred Lateral Discontinuity
Distorted Sounding (Due to Cultural Interference)
Laterite Soil (Clay Rich Layer)
Dry Clay Poor or Fresh-Brackish Water Saturated Volcanics
Inferred 2-D Structure (Possible Ash Falls, Weathered Volcanics or Intrusives)
Seawater Saturated Volcanics
500 Ft.
1000 Ft.
Scale in Feet
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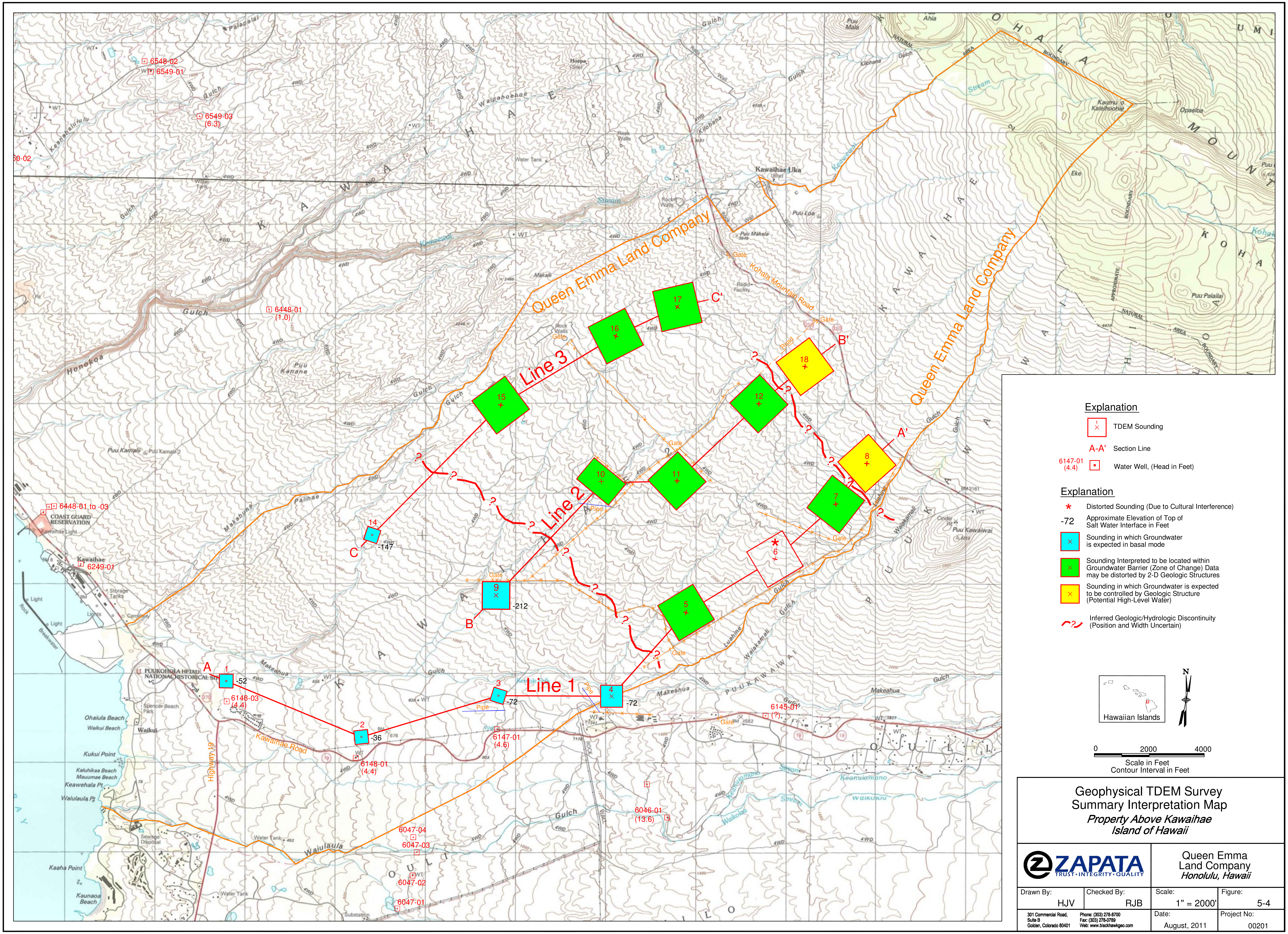
Queen Emma Land Company
Honolulu, Hawaii
Geoelectric Cross-Section from 1-D TDEM Inversions Line 3 C-C'
Property Above Kawaihae Island of Hawaii
Project No: 00201
Date: August, 2011
Drawn By: HJV
Checked By: RJB
Scale: As Shown
Figure: 5-3



Queen Emma Land Company
Queen Emma Land Company
Line 1
Line 2
Line 3
A
A'
B
B'
C
C'
1
-52
2
-36
3
-72
4
-72
5
6
7
8
9
-212
10
11
12
14
-147
15
16
17
18
6548-02
6549-01
6549-03
(6.3)
6448-01
(1.0)
6448-01 to -03
6249-01
6148-03
(4.4)
6148-01
(4.4)
6147-01
(4.6)
6145-01
(?)
6046-01
(13.6)
6047-04
6047-03
6047-02
6047-01
COAST GUARD RESERVATION
Kawaihae
PUUKOHOLA HEIAU NATIONAL HISTORICAL SITE
Kawaihae Road
Highway 19
Kohala Mountain Road
Kawaihae Uka
Puu Kanane
Puu Kamalii
Honokoa Gulch
Makeahua Gulch
Waiulaula Gulch
Ohaiula Beach
Waikui Beach
Kukui Point
Kaluhikaa Beach
Mauumae Beach
Kawehala Pt.
Waiulaula Pt
Kaaha Point
Kaunaoa Beach
Gate
Pipe
Explanation
TDEM Sounding
A-A' Section Line
6147-01 (4.4) Water Well, (Head in Feet)
Explanation
Distorted Sounding (Due to Cultural Interference)
-72 Approximate Elevation of Top of Salt Water Interface in Feet
Sounding in which Groundwater is expected in basal mode
Sounding Interpreted to be located within Groundwater Barrier (Zone of Change) Data may be distorted by 2-D Geologic Structures
Sounding in which Groundwater is expected to be controlled by Geologic Structure (Potential High-Level Water)
Inferred Geologic/Hydrologic Discontinuity (Position and Width Uncertain)
Hawaiian Islands
N
0 2000 4000
Scale in Feet
Contour Interval in Feet
Geophysical TDEM Survey
Summary Interpretation Map
Property Above Kawaihae
Island of Hawaii
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Land Company
Honolulu, Hawaii
Drawn By: HJV
Checked By: RJB
Scale: 1" = 2000'
Figure: 5-4
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Date: August, 2011
Project No: 00201

6.0 CONCLUSIONS AND RECOMMENDATIONS

The main objective of the TDEM surveys on the QELC property was to explore for potential basal and high-level groundwater resources at sounding sites near existing groundwater wells and at high elevation sites located above the town of Kawaihae, Hawaii. The optimum locations for basal mode groundwater are expected to occur where the thickest lens of fresh-brackish water is detected floating on seawater. The optimum locations for high-level groundwater are expected to occur above groundwater damming structures (i.e. dikes, intrusives) detected at relatively low surface elevations.

The results from the TDEM surveys are shown on Figures 5-1 through Figure 5-4 and Table 5-1. The general conclusions and optimum drilling locations interpreted from the TDEM soundings collected on the property are as follows:

1. **Line 1 - Transect A-A'**
   - Soundings 1, 2, 3 and 5 (which interpreted the groundwater heads in the area of the soundings to be 1.0 feet to 1.5 feet) were taken in the vicinity of State Wells (No. 6148-01 & 03, 6147-01 and 6145-01) located along the Kawaihae Road. A comparison of the sounding data with reported heads of 4.4 feet to 4.6 feet for these wells show fair to poor agreement in this area. Soundings 5 and 7 show intermediate resistivity layers occurring at depth and groundwater is expected to be located below sea level, but due to possible groundwater damming structures it is expected to be limited beneath these soundings. From the TDEM data a geologic/hydrologic discontinuity (i.e. 2-D structure, altered volcanics, ash flows, etc.) is interpreted between Soundings 7 and 8, which is possibly causing damming of groundwater in this area. The potential for fresh-brackish groundwater (in a high-level mode) is interpreted to exist beneath Sounding 8.

2. **Line 2 – Transect B-B'**
   - Beneath Sounding 9 the basal mode groundwater lens is interpreted to be 212 feet thick. Soundings 11 and 12 show high resistivity (113 ohm-m and 147 ohm-m) layers occurring at a depth of about 990 feet bsl. The potential for fresh-brackish groundwater appears to exist beneath these soundings, but may be limited due to possible groundwater damming structures (i.e. dikes) detected at depth in these areas. A geologic/hydrologic discontinuity (i.e. 2-D dike structure, altered volcanics, ash flows, etc.) is interpreted between Soundings 12 and 18. The potential for fresh-brackish groundwater, in a high-level mode, is interpreted to exist beneath Sounding 18, with high resistivity layers interpreted to depth of about 1,200 feet bsl.

3. Line 3 – Transect C-C'

- Beneath Sounding 14 the basal mode groundwater lens is interpreted to be 147 feet thick. Soundings 15, 16 and 17 show intermediate resistivity (84 ohm-m and 61 ohm-m) layers occurring at a depth of 425 feet bsl, 1,155 feet bsl and 554 feet bsl, respectively. The potential for fresh-brackish groundwater appears to exist beneath these soundings but it is expected to be limited due to groundwater damming structures (i.e. dikes, ash flows, etc.) detected at depth in theses areas.

Because of limited TDEM data in some portions of the project site, additional TDEM soundings located in areas where great distances occur (4,000 to 5,000 feet) between soundings will help to define the extent of potential basal and high-level groundwater resources in those areas of the property.

7.0 CERTIFICATION AND DISCLAIMER

All geophysical data analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by Zapata Incorporated Senior Geophysicists.

This geophysical investigation was conducted using sound scientific principles and state-of-the-art technology. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing, interpretation, and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review.

A geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations, or ordinances.

Jim Hild	Richard Blohm
Manager/Senior Geophysicist	Senior Geophysicist
Zapata Incorporated	Zapata Incorporated